FINAL PROGRESS REPORT

AND MANUAL

RUGGEDIZED INFRARED CARBON DIOXIDE ANALYZER

(NASA CONTRACT NO. NAS2-711)

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                Ames Research Center
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Submitted By: Beckman Instruments, Inc.
                Special Projects Division
                2400 Harbor Blvd.
                Fullerton, California

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Prepared By: Robert R. Pintar
                Robert R. Pintar, Project Engineer
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Approved By: Raymond L. Madsen, Chief Engineer

Approved By: Max D. Liston, Manager, Special Projects Division

AMES IR CO_2 ANALYZER

FINAL REPORT AND MANUAL

CONTRACT NAS2-711

CONTENTS

CONTENTS (CONT'D.)

LIST OF FIGURES

1.0 INTRODUCTION

This is the final report and instruction manual for the Ruggedized Infrared Carbon Dioxide Analyzer, NAS2-711. This report will be concerned with, 1) description of the instrument, including the theory of operation; 2) installation; 3) operating instructions and; 4) maintenance procedures.) A photograph of the completed instrument is shown in Figure 1.

1.1 References:- Beckman Proposal CS-61-131, June, 1961

Progress Report #1, January 31, 1962

Progress Report #2, March 1, 1962

Progress Report #3, April 4, 1962

Progress Report #4, May 10, 1962

Progress Report #5, June 5, 1962

Progress Report #6, July 18, 1962

Progress Report #7, August 20, 1962

Progress Report #8, September 18, 1962

1.2 Principles Of Operation Of The Pneumatic MONOBEAM Infrared Detector:-

The CO_2 sensor for the instrument is a pneumatic detector shown in diagram form in Figure 2. This detector is unique in that it is composed of a sample detector and a reference detector which are optically in tandem. Modulated infrared energy from the source is transmitted th.. ;h the gas sample being measured in cell #1, or the sample detector. Cell #1 is charged with CO_2. The infrared energy in the CO_2 absorption band is virtually eliminated in this first cell. The remaining energy is transmitted
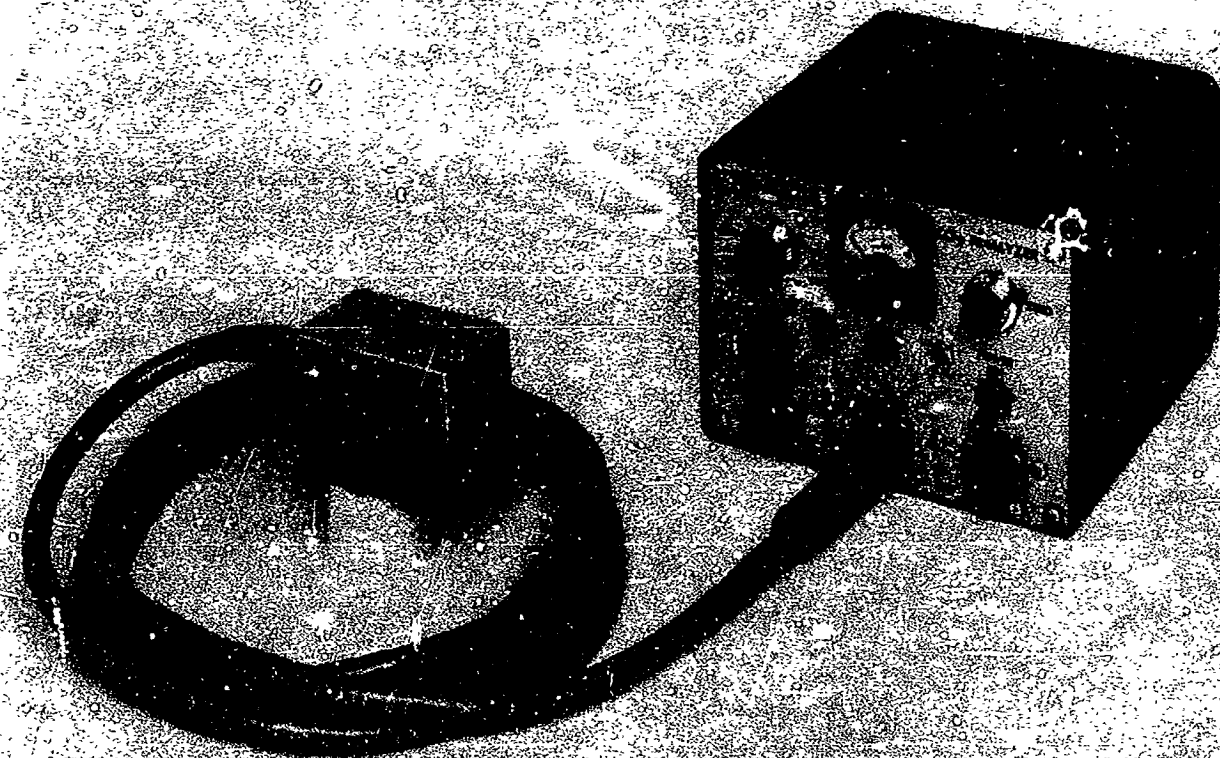
BECKMAN CO_2 ANALYZER
FIGURE 1
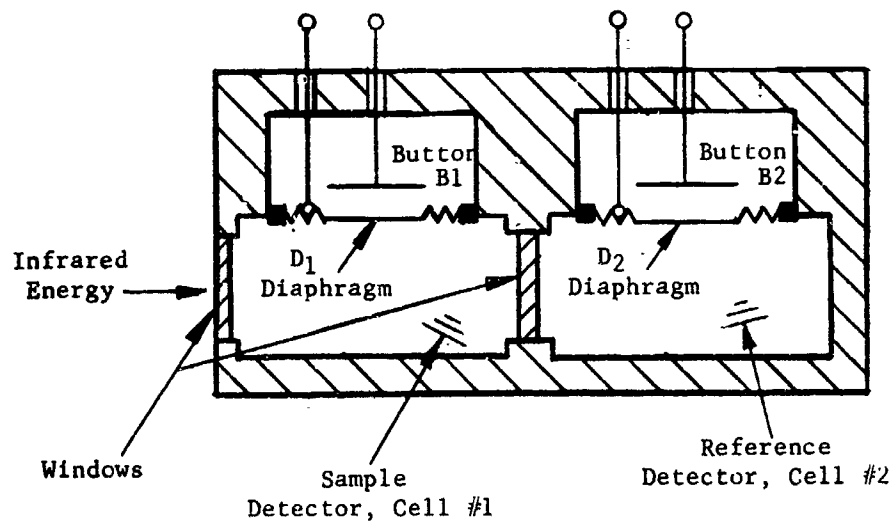
MONOBEAM PNEUMATIC DETECTOR

FUNCTIONAL DIAGRAM

FIGURE 2

into cell #2, or the reference detector. Cell #2 is charged with COS. In cell #2, the energy at the edge of the CO_2 absorption band is absorbed by the COS.) The result is a CO_2 sensor with a sample detector highly selective to infrared energy changes in the center of the CO_2 absorption band and a reference detector, highly selective to energy changes on the CO_2 band edge. When CO_2 is present in the gas sample being measured, cell #1 experiences a greater loss in received energy than cell #2. This relative change of absorbed energy is ultimately detected and used to indicate the concentration of the CO_2 in the gas sample being measured. The energy changes are detected by measuring the effect of a volume change produced in each of the cells. A thin diaphragm, indicated by D1 in cell #1, and D2 in cell #2, moves in response to the volume change and acts as the plate of a varying capacitor formed by the diaphragms and the fixed buttons indicated by B1 and B2 respectively. Each of the capacitors is biased with a d.c. voltage and produces an electrical signal in response to a capacitance change. In order to prevent damage to the thin diaphragms, from static pressure differences between the front and the back of the diaphragms, a by-pass hole is provided connecting the volumes on each side of the diaphragms. Thus, each cell will respond only to time varying changes in the incoming infrared energy. It is important to n⁻ ˙ this point the selection of a time varying infrared source ᴉ ₋ ˌ · ˌ ˸ for this purpose alone but primarily to enable sˑ ˌˑhronous deˌ ₋ . methods to be used for optimum signal to noise perfoᵣ̵man₋ᵤ. Since the input energy is time varying, an a.c. signal is produced in each detector cell. By biasing each of the diaphragm capacitors in opposition, the a.c. signals can be

made to cancel under the reference condition of no CO_2 in the gas
sample being measured. When CO_2 is present the a.c. signal from
the first cell drops due to the reduced infrared energy. The second
cell remains essentially unaffected, and an unbalance is produced
causing a signal to appear. This signal is then amplified and syn-
chronously rectified to indicate concentration of CO_2. Since the
detector functions with a single infrared source and utilizes a
common optical path for both the sample detector and the reference
detector, the name, "Pneumatic MONOBEAM Infrared Detector", is
applied. Since the MONOBEAM Pneumatic Detector contains both a sample
and reference detector in tandem, an inherent zero stability is ob-
tained. This is due to the fact that both the sample detector and
reference detector respond in the same manner to flat spectral changes
in infrared energy due to source deterioration and intensity variation
or dirt on the detector and source windows. Since the output of the
MONOBEAM detector is the difference between signals obtained from the
reference detector and the sample detector, these above factors will
not influence the zero signal or balanced detector conditions.

1.2.1   CO2 Measurement System Description:- A block diagram of the
Ruggedized Infrared CO_2 Analyzer is shown in Figure 3. The pneu-
matic detector receives modulated infrared energy from the source
after having been passed through the gas sample cell. The detector
is biased by a voltage (E), of which a voltage E1 is impressed
on cell #1 and a voltage E2 on cell #2. These voltages are varied
to obtain a zero or balanced electrical output from the detector.
The electrical output of the detector is directed into a high
impedance preamplifier containing two Nuvistor electrometer ampli-
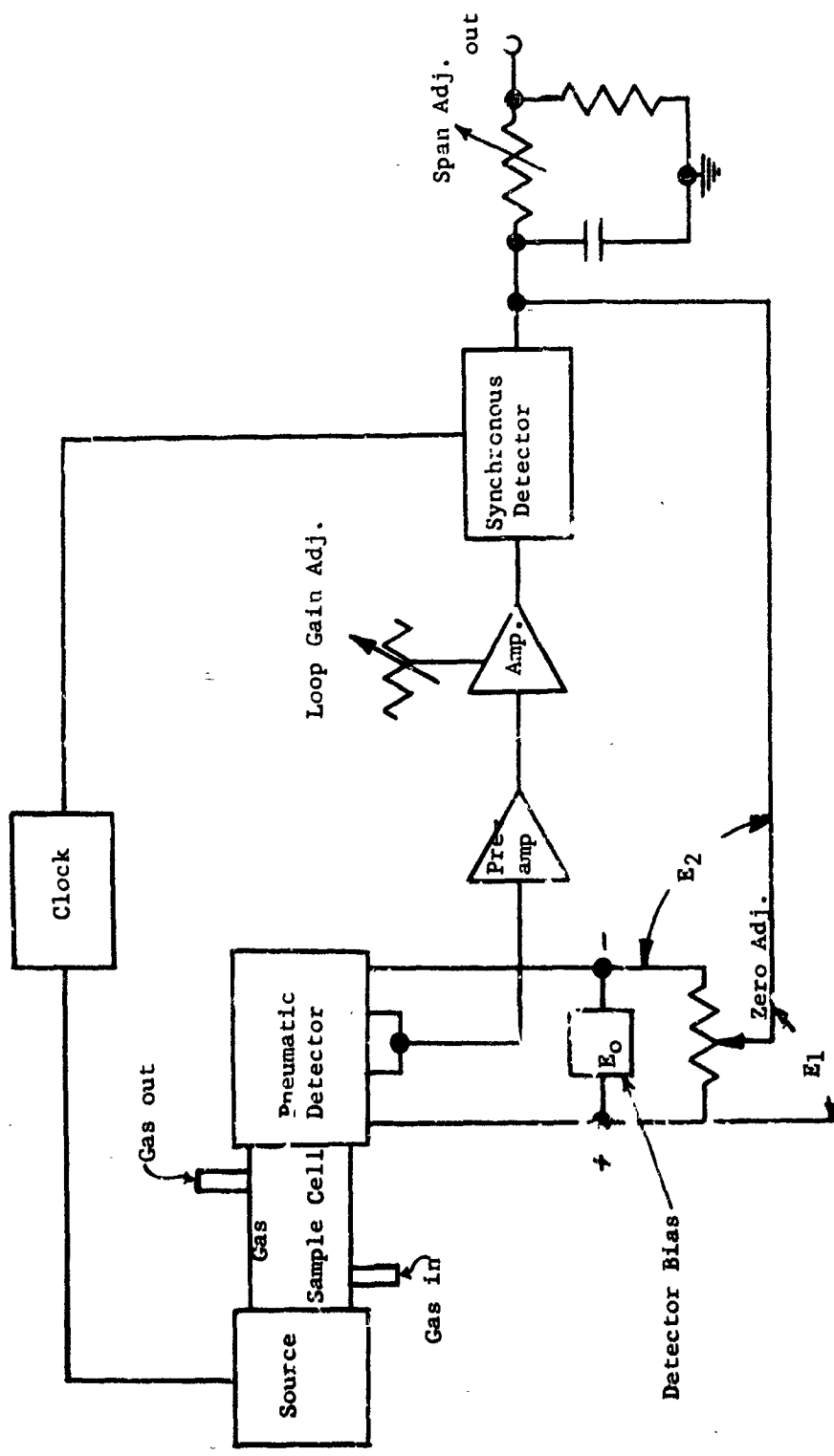fiers and a third transistor amplifier stage. The preamplifier

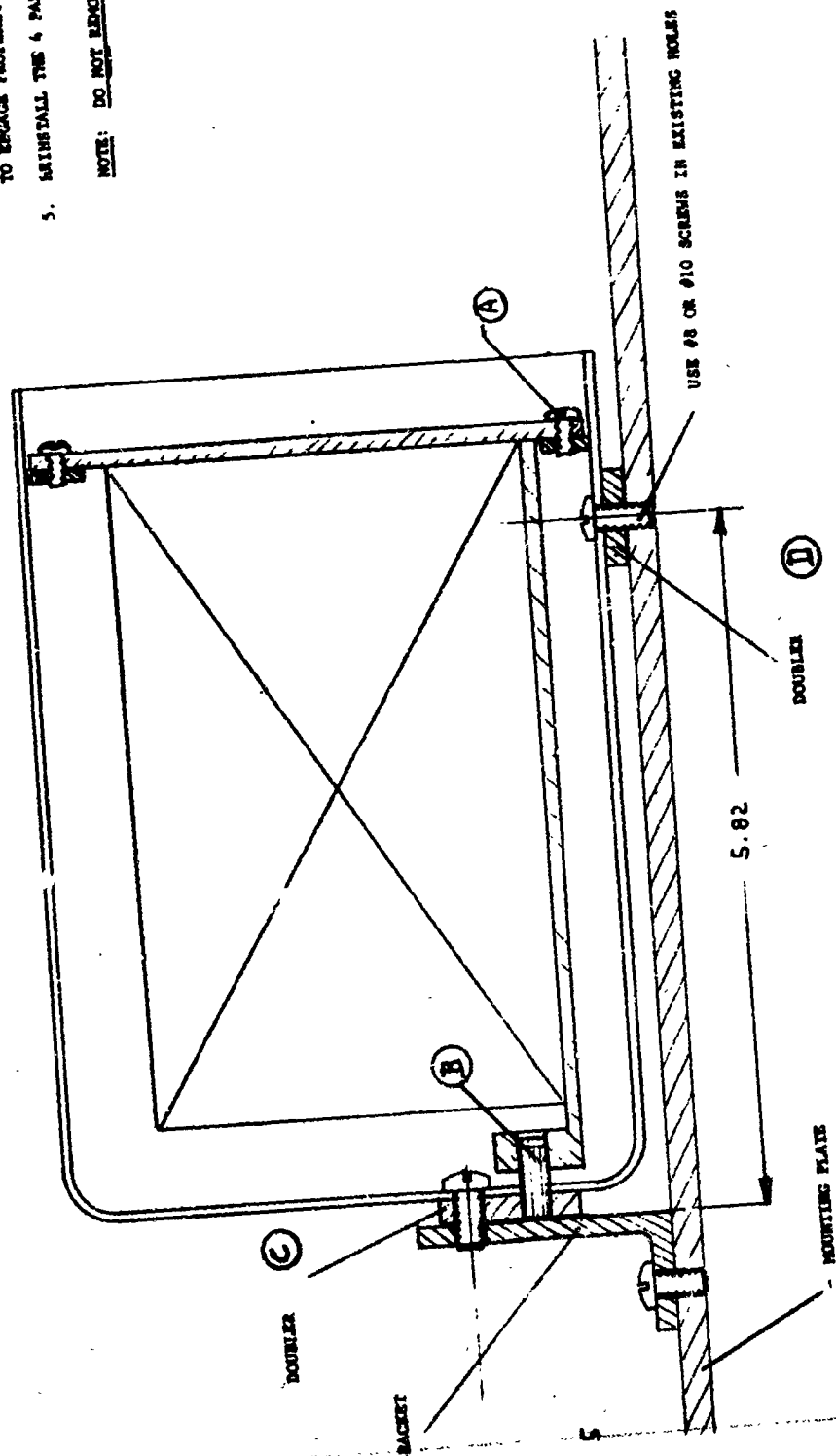FIGURE 3

CO_2 ANALYZER BLOCK DIAGRAM

is connected to a main amplifier having an adjustable gain potentio-meter which is used to set the loop gain of the electronic feedback system. The output of the amplifier is connected to a synchronous detector or rectifier which is switched under the control of the clock. The clock also turns the infrared source on and off, conse-quently establishing synchronism between the modulated infrared energy and the synchronous detector. The synchronous detector allows the detection or rectification of the electrical signals having a fre-quency equal to that of the source variation. This enables it to dis-criminate against other sources of electrical signals which are not of the same frequency or in synchronism with the switching of the syn-chronous detector. This method of detection is quite commonly used in order to detect a signal of known frequency and phase in the presence of incoherent noise or other sources of electrical interfer-ence. The output of the synchronous detector is a d.c. voltage pro-portional to the magnitude of the time varying electrical signal output of the pneumatic detector. This d.c. is directed to the output termin-als through a potentiometer which is used to control the range of the output voltage or the span of the instrument. This d.c. is also fed back to the zero adjust potentiometer to complete a feedback loop from which a ratio system is achieved. By means of this feedback loop the output voltage of the synchronous detector becomes an error signal proportional to the unbalance of the pneumatic detector. This signal is characterized by the following features:

    a. It is insensitive to variations in intensity of infrared

        energy due to deterioration of the source and loss in

MOUNTING PROCEDURE

1. REMOVE 4 FASTENING SCREWS - (A).
2. REMOVE AMPLIFIER FROM ITS CASE.
3. INSTALL CASE AS SUGGESTED.
4. SLIDE CHASSIS BACK IN CASE AND MAKE SURE TO ENGAGE PROPERLY OVER SHOCKPINS - (B).
5. REINSTALL THE 4 PANEL FASTENING SCREWS.

NOTE: DO NOT REMOVE DOUBLER - (C) and (D).

USE #8 OR #10 SCREWS IN EXISTING HOLES

5.82

DOUBLER

MOUNTING PLATE

DOUBLER

BRACKET

SUGGESTED INSTALLATION FOR CO₂ ANALYZER AMPLIFIER

FIGURE 4

SUGGESTED CABLE SUPPORT TO ELIMINATE

EXCESSIVE STRAIN ON DETECTOR LEADS

1/4 - 20

1.15

.32

APPROX. 4 INCHES

MAXIMUM LENGTH
5/16"

DEPTH 3/16"
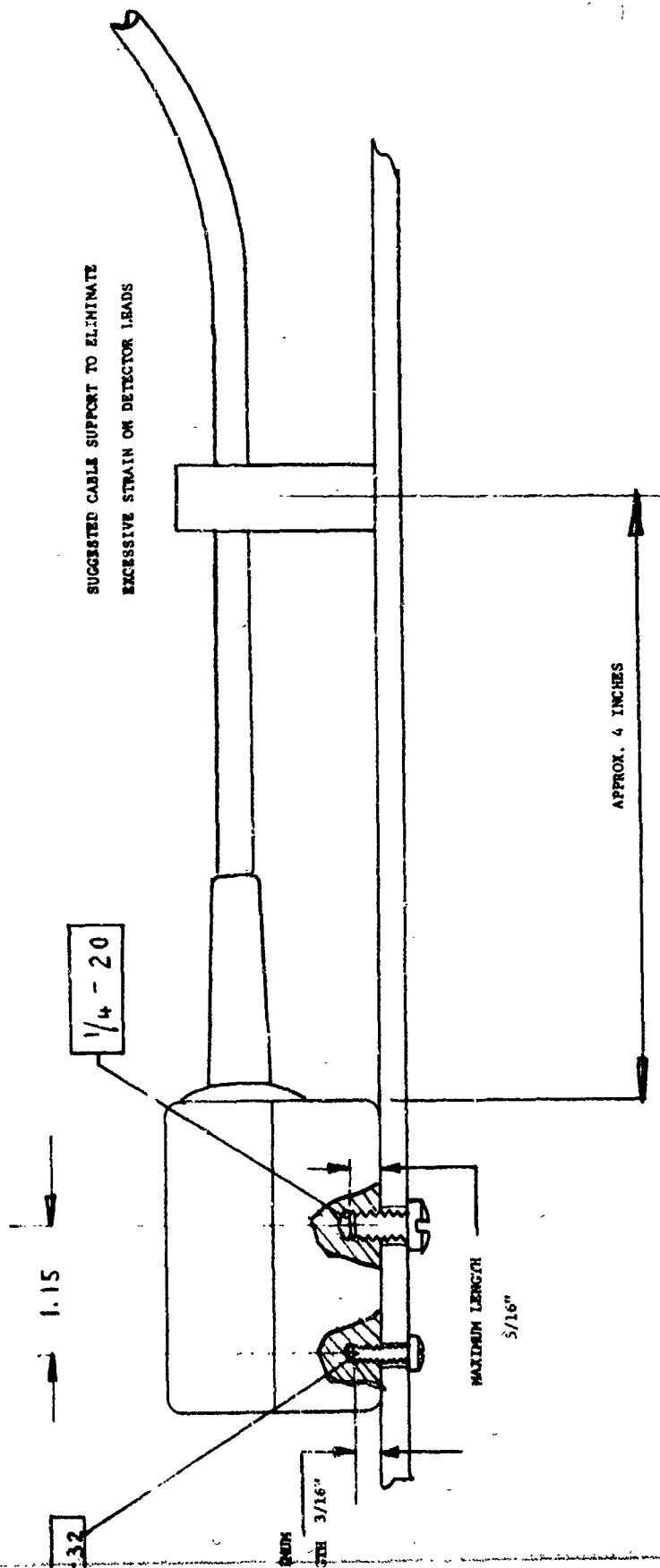
SUGGESTED DETECTOR INSTALLATION

FIGURE 5

2.2   Electrical Connections:- There are three receptacles provided on the front panel of the control unit. One is for power input, one for output and one for connection to the detector.

2.2.1   Input Power:- This instrument has been designed to operate on 380 to 420 c.p.s., 110 to 120 VRMS only. The instrument has an isolation transformer so that a grounded power supply may be used. The power receptacle connections are tabulated below.

Pin	Connection
A	Chassis Ground
B	Unused
C	400 ± 20 c.p.s., 115 ± 5 VRMS
D	400 ± 20 c.p.s., 115 ± 5 VRMS
E	Unused

The chassis ground, pin A, may be used to bond the chassis to ground if required. The instrument is protected by a 1/2 amp. 3 AG fuse. Accidental connection of the instrument to 60 c.p.s., 115 V power will cause the fuse to blow but will not cause other damage.

2.2.2   Recorder Output:- The instrument output is available at pins C and D of the recorder receptacle. Pin C is the high side and pin D is the low side. The remaining pins are unused. The output is in parallel with the voltmeter on the panel. Full scale on the voltmeter is approximately 2 volts d.c. The impedance of the recorder output is about 20,000 ohms.

2.2.3   Detector:- The detector connector has an interlock so that the input power is interrupted if the detector is disconnected while the instrument is on. This protects the preamplifier filament power supply Zener which will become overheated if the instrument is operated with

the filaments disconnected. The electronics may be operated without the detector connected, by shorting pins K and L and connecting a 60 ohm, 1 watt resistor across pin H and J of the twelve pin connector located in the lower center of the front panel.

2.3 Sampling System:- A sampling system is required to drive the sample gas through the detector sample cell. A typical sampling system is shown in Figure 6. It consists of a suitable vacuum pump, a restrictor valve for flow control, a flow gauge and a catheter sampling tube. The catheter tube should have a 1/16" I.D. and may be up to six feet in length. Larger inside diameters will result in an apparent loss in response due to mixing in the tube. Smaller diameters will result in excessive pressure drops causing a possible instrument span error.

> IMPORTANT NOTE: ALL RESTRICTIONS IN THE SAMPLING SYSTEM
> FOR THE PURPOSE OF FLOW CONTROL SHOULD BE LOCATED DOWN-
> STREAM OF THE DETECTOR. ANY RESTRICTION OF THE SAMPLE
> GAS UPSTREAM OF THE DETECTOR MAY CAUSE A REDUCTION OF
> PRESSURE IN THE SAMPLE CELL, RESULTING IN SERIOUS SPAN
> ERRORS.

The sample vacuum pump should be capable of drawing a continuous sample of 1000 ml per minute. A sample rate of 500 ml per minute is recommended for normal operation.

3.0 OPERATION

3.1 Controls and Switches:- The instrument is equipped with the following controls:

Power On-Off Switch

Fine Zero

Catheter

Detector

Flow Gauge

Flow Control

Pump

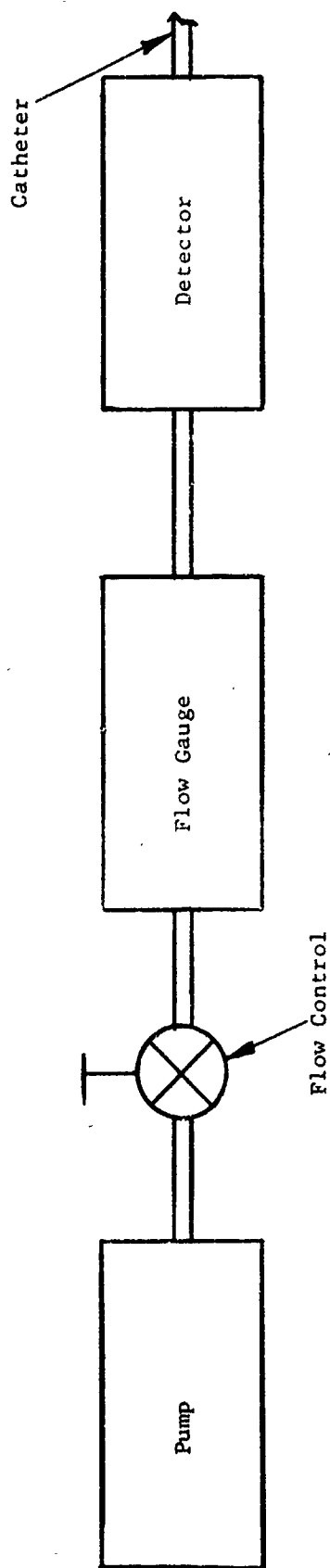FIGURE 6

Span

Coarse Zero

Calibrate Test Button

Loop Gain Test Button

3.1.1   Power On-Off Switch:- The power switch is a double pole single throw. When it is off, both sides of the line are disconnected from the instrument. Power can only be applied to the instrument when the detector plug is connected because of an electrical interlock included in the detector connector. The input power circuit is completed through pins K and L of the detector connector. Application of power is indicated by the red indicator lamp on the front panel.

3.1.2   Fine Zero:- The fine zero is used to zero the instrument under the presence of 0% CO_2 in the sample cell. The panel meter provides the visual readout for making the zero adjustment. Final zero adjustments should be made after allowing the instrument to warm up for at least one hour.

3.1.3   Span:- The span control is used to adjust the instrument for a particular output voltage or meter reading for a given percentage of CO_2 in the sample cell. The instrument is limited by the sample cell to about 10% CO_2. The span control is capable of providing a full scale reading for about 4% CO_2 in the sample cell. The span control was factory adjusted to yield a full scale deflection with 8% CO_2 in the sample cell.

> NOTE: ALL SPAN CONTROL ADJUSTMENTS SHOULD BE MADE WITH THE RECORDER CONNECTED TO THE RECORDER CONNECTOR BECAUSE OF THE LOADING EFFECTS OF THE RECORDER.

3.1.4   Coarse Zero:- The coarse zero is a screw driver adjustment available through a hole in the front panel. This control provides essentially the same action as the fine zero but with less resolution. The coarse zero

was factory adjusted for instrument zero with the fine zero in its mid position. The coarse zero should require little attention since most of the instrument drift will be well within the range of the fine zero adjustment.

3.1.5   Calibrate Adjust:- The calibrate adjust is a screw driver adjustment available through a hole in the front panel. The range of this control will vary between instruments but should yield about 1/2 scale deflection when the calibrate test button is pressed. The calibrate control is adjusted with the calibrate test button pressed to provide a given output indication with 0% CO_2 in the sample cell. This adjustment is usually made after the span adjust has been set, using no CO_2 gas mixtures in the sample cell. After the span is set, the calibrate control is adjusted to provide a given meter or output indication within its range with 0% CO_2 in the sample cell.

3.1.6   Calibrate Test Button:- The calibrate test when pressed produces an electrical signal equivalent to CO_2 in the sample cell. The exact amount of CO_2 that it represents is determined by the span and calibrate adjust controls. The purpose of this test button is to determine the status of the instrument or make span adjustments in the absence of known CO_2 sample gas mixtures.

3.1.7   Loop Gain Test Button:- This control indicates the instrument loop gain. This test should only be done with 0% CO_2 in the sample cell. The output indication when this test button is pressed is an inverse function of the loop gain. For this instrument, loop gain indications should be between 2% and 4% of full scale for satisfactory operation.

3.2   Warm Up:- Maximum accuracy and stability will be attained after the instrument has reached a stable operating temperature. This will take approximately one hour if the instrument has been installed in accordance with paragraph 2.1. If the detector is not mounted to the suggested heat sink, the detector will experience a greater temperature rise (30°C) and a longer period of time will be required to reach a stable operating point (4 to 6 hours). Operation of the detector in this manner will not cause damage. The electronics portion of the instrument does not require a heat sink under normal operating conditions.

3.3   Sample Gas:- The sample gas is drawn through the detector sample cell with a small vacuum pump (not supplied with the instrument). A pump that can continuously draw a sample of 1000 milliliters per minute with a suitable length of 1/16" I.D. catheter is recommended. The response time of 0.2 seconds to 90% of final reading is obtainable when the sample gas flow is at least 500 milliliters per minute. Lower sample gas flow rates will result in slower responses.

      IMPORTANT NOTE: ADJUSTMENT OF THE FLOW RATE SHOULD BE ACCOMPLISHED BY A THROTTLING VALVE INSERTED BETWEEN THE DETECTOR AND PUMP. ADJUSTMENT OF THE FLOW RATE BY RESTRICTING THE SAMPLE GAS INLET SIDE OF THE DETECTOR MAY RESULT IN A REDUCTION OF PRESSURE IN THE SAMPLE CELL WHICH COULD CAUSE A CONSIDERABLE SPAN ERROR.

3.4   Calibration:- This instrument was designed for operation into a recorder. The meter on the front panel was provided to aid in zero

adjustment and initial setup of the instrument only. All calibration should be accomplished with the intended recorder connected.

Calibration of the instrument is accomplished by the measurement of known concentrations of CO_2. Calibration should be done after the instrument is installed as outlined in Section 2.0 and allowed to reach stable operation as described in paragraph 3.2. For best results, the calibration should be performed by duplicating, as closely as possible, the conditions under which the instrument is to be used, such as, mounting, ambient temperature, flow rate, and catheter lengths. The calibrating gas should be allowed to enter the sample cell through the catheter. Care should be taken in connecting the catheter to the calibrating gas supply so that no restriction occurs upstream of the detector. This can be accomplished by placing the catheter loosely in a larger tube coming from the calibrating gas supply. The calibration gas flow must be greater than that drawn by the catheter. Another method would be to connect the calibrating gas supply to the catheter through a plastic bag to prevent pressure changes in the sample cell due to unequal flow rates. The CO_2 sensor is nonlinear so more than one calibrate gas mixture will be required to determine the transfer characteristic. The number of mixtures required will be determined by the expected accuracy. The diluent gas will affect the calibration of the instrument because of an effect referred to as "collision broadening", where the absorption characteristic is affected by the diluent gas. However, the maximum expected error in going from a diluent of 100% O_2 to 100% N_2 is less than 1%.

The instrument zero can be accomplished by evacuation of the sample cell or by using 100% N_2 as a sample gas. The use of normal room temperature may also be employed as the CO_2 content is usually

only about .05%. The use of the span and calibrate adjust and push button is described in paragraph 3.1.

4.0   MAINTENANCE

The following procedures, with the exception of paragraph 4.1, describe critical factory adjustments which should not be attempted unless absolutely necessary and only when the proper equipment is available.

4.1   Sample Cell Cleaning:- Continued use of the instrument will result in an accumulation of dirt in the sample cell. This reduces the magnitude of the infrared energy reaching the detector, resulting in a reduction of loop gain. The calibration of the instrument will not be seriously affected, however, the response of the instrument will be reduced by a proportional amount. The sample cell may be easily cleaned with the aid of the following procedure:

4.1.1   Removal of Source and Sample Cell Block:-

    a.   Disconnect sampling tubing to Luer Lock connectors.

    b.   Unscrew one (1) cap screw (6-40 thread) at the cable end of the cover.

    c.   Unscrew both screws (10-32 thread) from cable end of detector. NOTE: NEVER REMOVE SCREWS ON OTHER END.

    d.   Pull out the source and sample cell block approximately 1/16", then tilt it and remove as shown in Figure 7.

4.1.2   Cleaning the Detector Windows:- The window on the detector is now exposed for cleaning. Wipe it with a tooth brush and detergent solution. In case of hard crust deposit, such as dry mucus, a razor blade can be used to remove the deposit. Due to the hardness of the window material (synthetic sapphire) no damage will occur. Rinse with clean

FIGURE 7

SOURCE REMOVAL DIAGRAM

SCREWS FOR REMOVAL OF
SAMPLE CELL

SOURCE CONTACTS

SEPARATE

TILT

NEVER
REMOVE THESE SCREWS

LIFER LOCK INSERTS
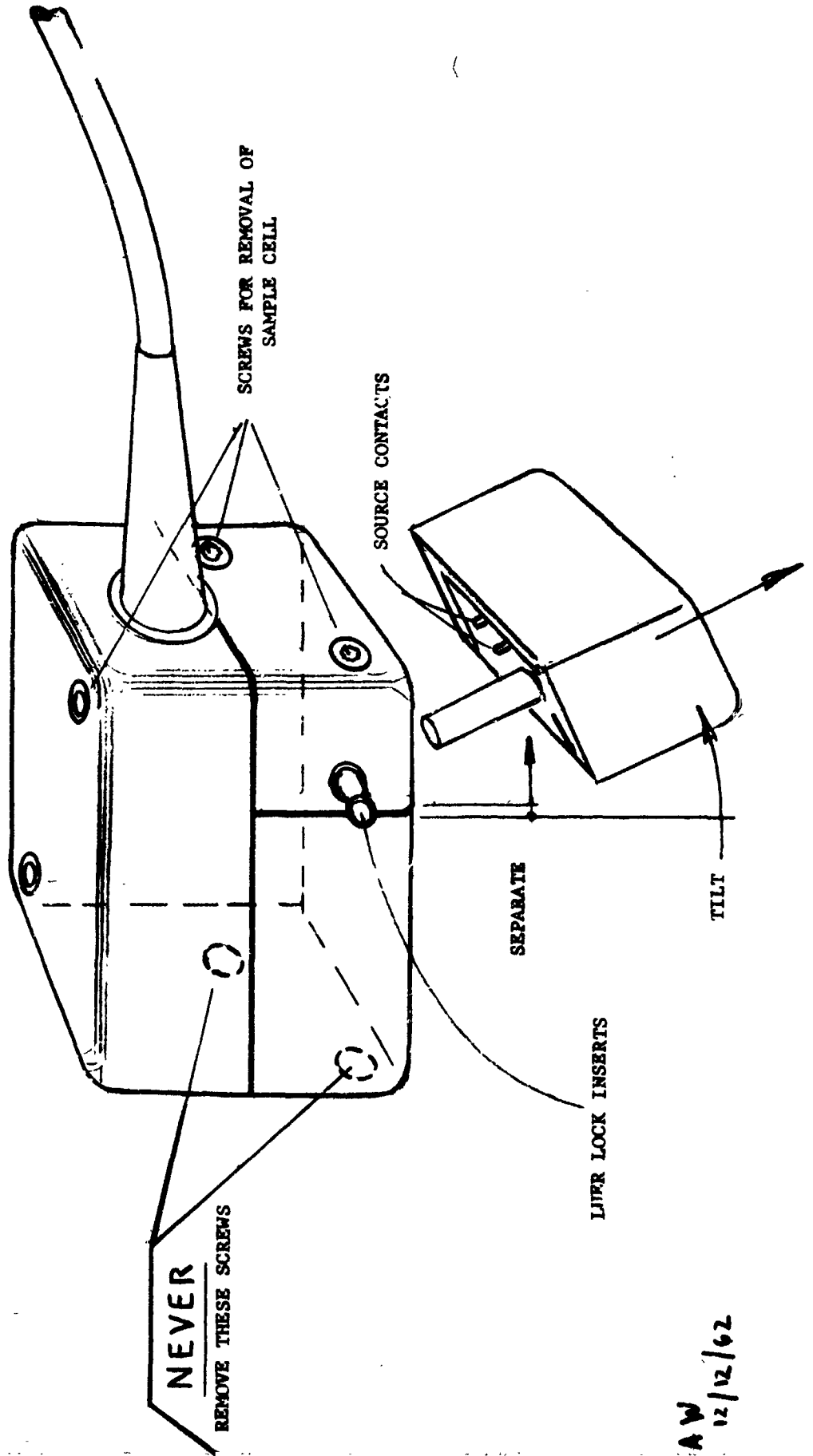
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water and dry with a clean cloth. CAUTION: PREVENT SOLUTION FROM RUNNING INTO PREAMPLIFIER SECTION UNDER THE COVER.

4.1.3   Cleaning of the Sample Compartment in the Source Block:- Remove the "O" ring and dispose of it in case of damage or deterioration. The complete block can now be clean d y immersion into a detergent solution. The window, in case of hard deposit, can be scraped with a pen knife or similar tool. Final clean and dry the same as the detector window. Replace "O" ring. CAUTION: CARE SHOULD BE TAKEN SO AS NOT TO ACCIDENTALLY BEND THE SOURCE CONTACT PINS.

The bores, .055 diameter, on inlet and outlet of the sample cell can be cleaned with a wire or suitable size drill. The Luer Lock fittings can be unscrewed. When reinstalling them, turn until seated against the nylon washer then tighten from 1/4 to 1/2 turn. Replacements for the Luer Lock insert and its nylon seal washer can be obtained from Beckman Instruments, Inc.

4.1.4   Reassembly:- Follow the disassembly sequence in reverse. In case of difficulties, loosen the other cover screw by one to two turns. Do not remove the cover unless absolutely necessary. Make sure the spring contacts to the source pins are properly engaged.

The soft metal gasket (indium) between the cover and detector body is not an absolute necessity but it will help to keep dirt out of the preamplifier section. The material can be obtained from Beckman Instruments, Inc., Special Projects Division. Insert narrow strip, approximately 1/8" wide, between the cover and body. Tighten the cover down evenly with both screws and cut off the excess with a

pocket knife. CAUTION: BE CAREFUL NOT TO GET STRIP IN CONTACT
WITH EXPOSED WIRES INSIDE.

4.2   Quadrature Adjustment:- A quadrature voltage will exist when the de-
tector is balanced if the phase angle between the detector and reference
cells is not exactly 180°. The quadrature voltage is undesirable. It
serves no useful purpose and causes an increase of ripple at the out-
put of the instrument. The quadrature voltage could also result in
amplifier saturation if it becomes excess. The quadrature voltage is
minimized by adjustment of one of two magnetically operated pneumatic
valves located in each cell of the detector. The quadrature voltage
is excessive if the 40 c.p.s. ripple at the output of the instrument
exceeds .050 volts peak to peak. It is possible to reduce the ripple
to less than .025 volts peak to peak by adjustment of one of the
magnetic valves with a strong horseshoe permanent magnet, having an
air gap of approximately 1/4". The magnetic valves are located under
nonmagnetic stainless steel covers located on the back and side of
the detector. The valve stem has a magnetic bar located directly
under the round stainless steel cover. The valve may be rotated with
the magnet as shown in **Figure 8**. Each of the two valves is rotated
while the 40 c.p.s. ripple on the instrument output is observed. Each
valve is rotated independently until the ripple is minimized. There
is an infinite combination of the two relative valve positions that
will result in minimum ripple. The most desirable combination is that
which results when one of the valves is fully closed as this results
in maximum detector signal to noise ratio. It may be necessary to
readjust the phase and loop gain controls after the quadrature voltage
has been minimized.

CLOSE
CLOCKWISE

OPEN
C. CLOCKWISE
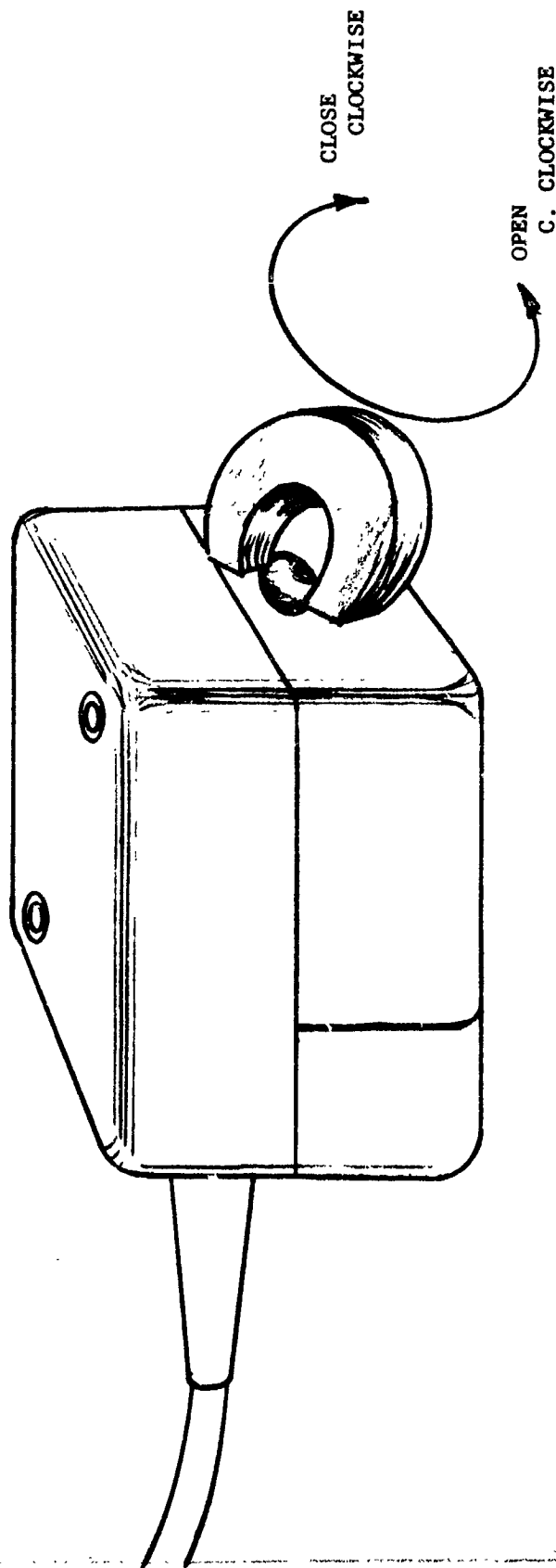
MAGNETIC VALVE ADJUSTMENT
DIAGRAM

FIGURE 8

An alternate method for minimizing the quadrature and one that may have to be used if the quadrature signal is excessive is given below.

a. Prepare the instrument for normal operation, except that the electronics should be removed from its enclosure.

b. Remove the demodulator board completely from its socket.

c. Connect a cathode ray oscilloscope (CRO) between the base of Q9 on the amplifier and the instrument common.

d. Apply power to the instrument and allow it to warm up for several minutes.

e. Close fully both magnetic valves, using the magnet as shown in Figure 8.

f. Adjust the fine zero, and coarse zero if necessary for minimum 20 c.p.s. signal on the CRO.

g. Rotate one of the magnetic valves until there is a noticeable change in the signal appearing on the CRO.

h. Readjust the fine zero for minimum signal. If this value is less than the value observed in "f", repeat "g" and "h" until a minimum minimum is achieved. If this value is larger than that of step "f", return the valve to the fully closed position and go back to step "g", rotating the other valve.

This procedure should result in a quadrature signal of 1/2 volt peak to peak or less. This adjustment is somewhat difficult because of the harmonic content of the waveform.

After the quadrature has been minimized, using the alternate procedure, the phase and loop gain adjustments should be checked.

4.3 Phase Adjustment:- Correct phasing of the instrument results in max-

ture component. The phasing is adjusted with the aid of the following procedure:

a. Prepare the instrument for normal operation, except that the electronics should be removed from its enclosure.

b. Remove the demodulator board completely from its socket, Figure 9.

c. Connect a dual trace CRO as follows: Channel A between the emitter end of R52 and instrument common and channel B between clock board pin A and instrument common. A single trace CRO may be used if the square wave, ± 12 volts, 20 c.p.s., available at pin A of the clock board and instrument common, is used to trigger the CRO horizontal sweep.

d. Adjust the fine zero and coarse zero, if necessary, to obtain 3 volts peak to peak on channel A, as shown in Figure 10. Two positions of the zero pot, one on either side of balance, will yield the required signals, which will be about 180° apart. CW rotation of the zero control should yield curve (1). The phase pot should be rotated until curves (1) and (2) are symmetrically located with respect to the square wave on channel B, Figure 10.

CAUTION: EXTREME ROTATION OF THE PHASE POT MAY RESULT IN A COMPLETE PHASE REVERSAL, THAT IS, CW ROTATION OF THE ZERO POT FROM BALANCE YIELDING CURVE (2) FIGURE 10, INSTEAD OF CURVE (1). THE INSTRUMENT WOULD BE INOPERATIVE UNDER THESE CONDITIONS AS IT WOULD BE IMPOSSIBLE TO OBTAIN

Demodulator Board

| L | K | J | H | F | E | D | C | B | A |

Phase
Adjust

Gain
Adjust

Amplifier
Board

POWER SUPPLY

BOARD

Clock
Board

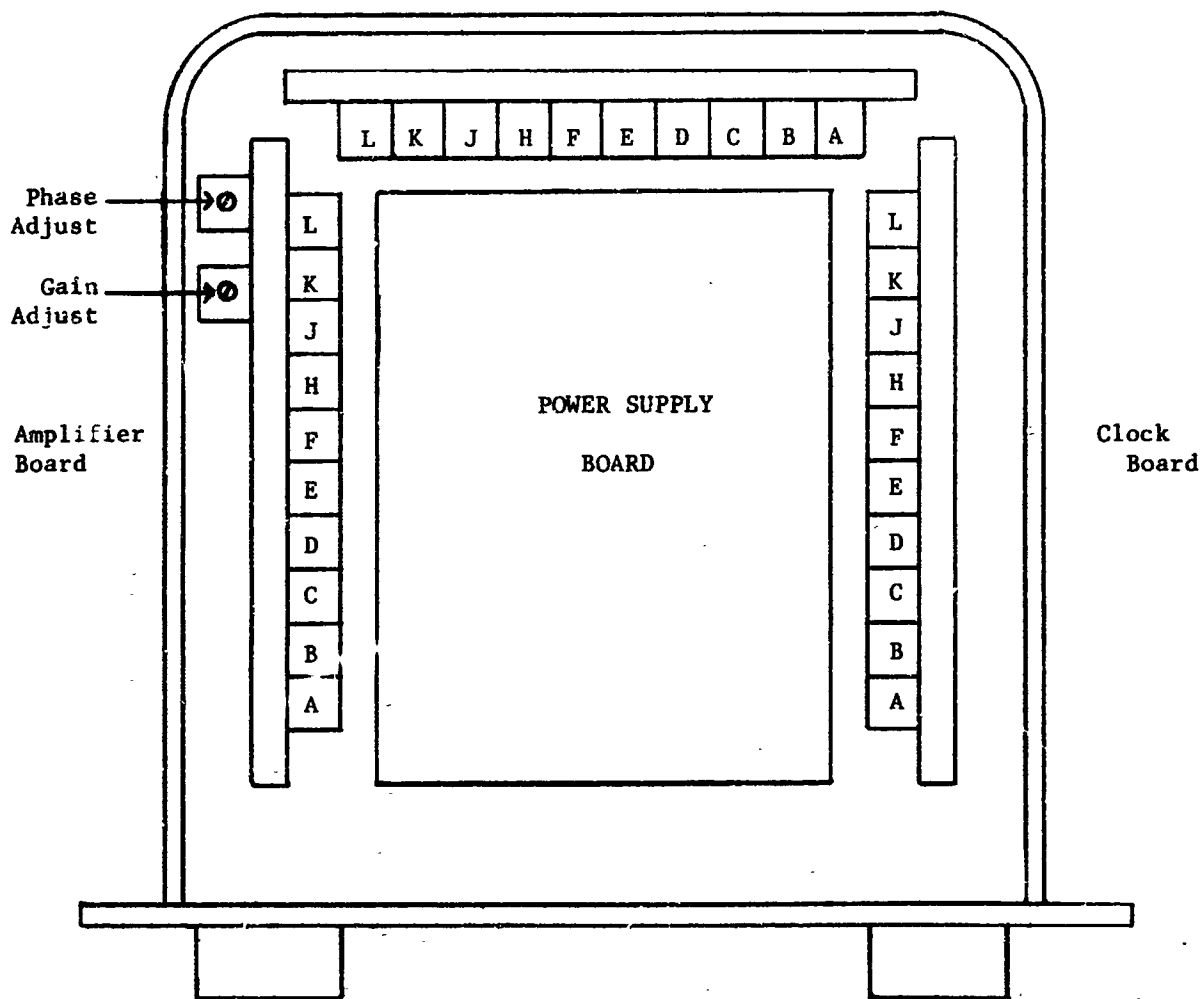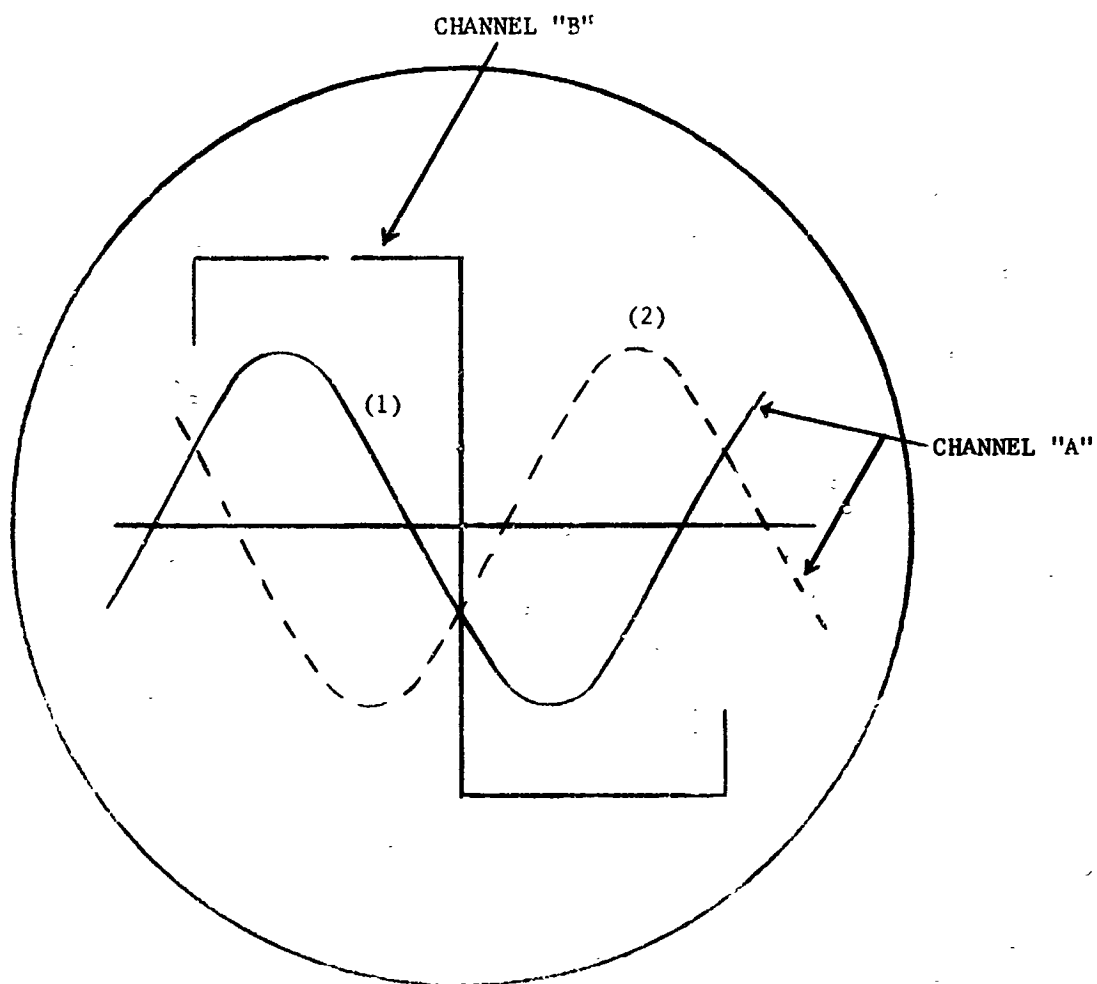| Left column	Right column
L	L
K	K
J	J
H	H
F	F
E	E
D	D
C	C
B	B
A	A

FIGURE 9

FIGURE 10

Proper phasing of the instrument will result in maximum obtainable loop gain. After phasing it may be necessary to retouch the loop gain control as described in paragraph 4.4.

4.4   Loop Gain Adjust:- The instrument loop gain is controlled by the Trimpot located on the amplifier board as shown in Figure 9. The loop gain should be increased until the response of the instrument is critically damped. This can be accomplished by rotating the loop gain pot CW until the output "rings" slightly when the catheter is quickly placed in a stream of 8% CO_2. The flow rate through the sample cell should be 500 ml per minute and the output displayed on a CRO, or other suitable recorder. (Do not attempt to use the panel meter to determine the response). The gain should then be reduced until the ringing in response to stepped changes in CO_2 just disappears. Do not attempt loop gain adjustments unless the phasing, paragraph 4.3, and quadrature, paragraph 4.2, are known to be correct.

4.5   Detector Compensation:- The compensation network consists of C16, C17, C36, and R15. The purpose of this network is to minimize the response of the preamplifier to changes in the cell bias due to feed back. A simplified schematic of the compensation network and associated circuitry is shown in Figure 11. D_1 and D_2 are the detector and reference cell capacities respectively. R13, R15, and C36, are located in the preamplifier while C16 and C17 are located with the electronics. C_8 represents the grid to ground capacities associated with V_1, and any strays that may exist. When the network is properly adjusted, that is, characteristics of the network made up of C16, C17, C36, and R15, are identical to those of the network made up of D_1, D_2,
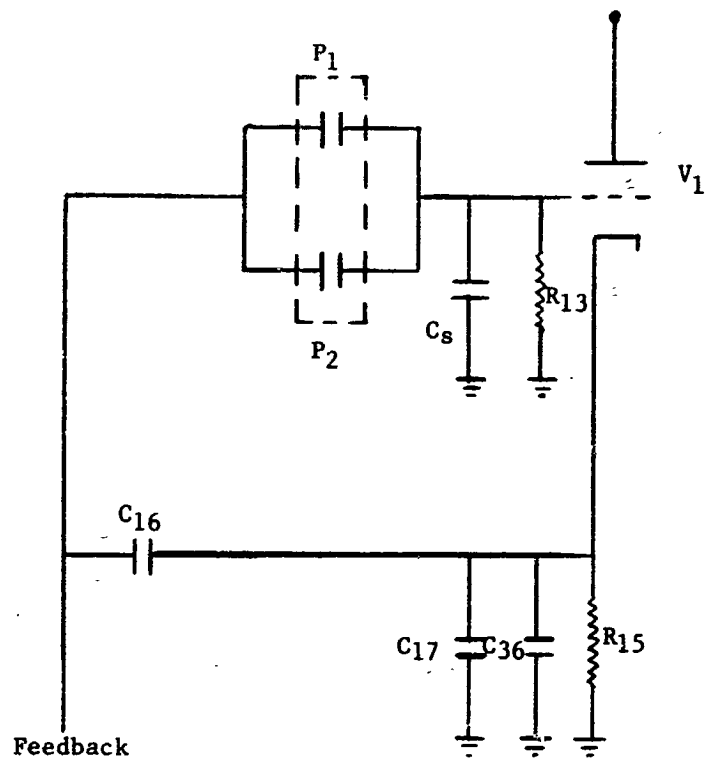
FIGURE 11

C_s, and R13, the voltages appearing at the grid and cathode of V_1, as a result of a voltage applied at F.B., are equal and do not appear on the plate of V_1. The changes in detector output appearing at the grid only of V_1, as a result of changes in the voltage appearing at point F.B., are not affected by the compensation network. Misadjustment of the compensation network will result in erratic operation of the instrument and possible oscillation. The compensation may be adjusted with the aid of the following procedure.

a. Prepare the instrument for normal operation except that the electronics should be removed from its enclosure.

b. Remove the demodulator and clock boards completely from their sockets.

c. Connect a CRO between the base of Q9 and instrument common.

d. Connect an audio oscillator between the center tap of the coarse zero and instrument common.

e. Remove completely C16 and C17, located on the power supply board, and temporarily connect in their places, two capacitor decade boxes variable from .001 to 1 mfd.

f. Adjust the decade capacitor in place of C16 to .25 mfd and the decade capacitor in place of C17 to .15 mfd.

g. Adjust the output of the audio oscillator until a signal of about 15 volts peak to peak appears on the CRO. (A slight clipping may occur.)

h. Adjust C17 for minimum signal.

i. Increase C16 by .01 mfd and readjust C17 for minimum

signal.

j. If the signal resulting from step "i" is less than
    that resulting from step "h", repeat step "i" until
    a minimum minimum signal is achieved. If the com-
    parison shows that it is larger, repeat step "i",
    decreasing C16 by .01 mfd. Increase the output of
    the signal generator as the correct adjustment is
    approached, until the output of the signal generator
    is 3 volts peak to peak. Correct adjustment of the
    compensation network is achieved when voltage on the
    base of Q9 is between 3 and 6 volts peak to peak and
    the output of the signal generator is 3 volts peak
    to peak. It may be necessary to use smaller incre-
    ments (.001 mfd) in step "i" to achieve this.

k. Replace the decade capacitors with fixed values made
    up of 2 or 3 paper or mylar dielectric capacitors as
    required, and recheck to see if the compensation is
    still within the limits outlined in step "j". (A
    difference may occur when the fixed values are installed,
    due to the dissipation factors of the decade and fixed
    capacitors.)

4.6   Resistance-Voltage Checks:- The following resistance-voltage check
        list may be useful in isolating a failure that may occur. Table I
        shows some of the power supply voltages that should exist at the
        printed circuit board sockets. These measurements may be taken with
        all boards removed. The clock output should be measured with all
        boards in place. The clock output should be a ±12 volt squarewave

board should be equal and 180° out of phase.

Table II shows the resistance and continuity checks that may be made at the connector of the detector assembly.

Board Pin	Amp	Demodulator	Clock
A	- 12	Clock	Clock
B	E_O	Clock*	Blank
C	$E_O{}^*$	Blank	- 25
D	+ 12	Common	+ 3
E	Blank	Key	Common
F	Blank	E_{out}	Key
H	Key	+ 12	Source Drive
J	Common	- 12	+ 12
K	Blank	$E_{in}{}^*$	Clock*
L	E_{in}	E_{in}	- 12

PRINTED CIRCUIT BOARD CONNECTOR PIN IDENTIFICATION

TABLE I

* Inverted

Connector Pin	Resistance To Case	Remarks
A	100K	
B	>100 Meg	<.1 ohm to pin F
C	>100 Meg	
D	22 to 26K	
E	50K to 10 Megs	This reading depends upon type of ohmeter used and polarity of connection.
F	>10 Meg	
H	10 to 20 ohms	Preamplifier filaments, cold.
J	<.1 ohm	
K	>100 Meg	<.1 ohm to pin L
L	>100 Meg	
M	>100 Meg	10 to 11 ohms to pin N
N	>100 Meg	

DETECTOR ASSEMBLY RESISTANCE AND CONTINUITY CHART

TABLE II

SOURCE

PREAMP

CLOCK

DETECTOR

D1

D2

R14
20Ω
C6
1,000 PF
C7
1000 PF
R17
51K
C9
47 MF
R19
11K
R71
510 Ω
Q1
2N2048

V1
7895
V2
7587

R13
110Ω
R15
100K
C36
.1 MF
R70
200Ω
R16
22MΩ
C8
15 MF
R18
5K
C10
.1 MF
R20
24K

Q8
2N1304
R3
50K
CR16
1N687
C11
.05 MF
R25
33K

R24
4.7K
CR17
1N687
C12
5.6 MF
Q5
2N1305

A B C D E F H J K L M N
A B C D E F H J K L M N
DETECTOR

Q2
2N1260

POWER SUPPLY

F1
1/4 AMP

POWER
INPUT
E
D
C
B
A

L1
NE

S1
SPDT

CR1
1N540
3
4
R37
300 Ω
10 W
C1
18 MF
C2
18 MF

CR2
1N540
5

R1
1.1K
1W
R2
1.1K
1W
R3
1.5K
+22

R4
1.1K
+12
CR3
1N1877A
R5
470 Ω
+12
CR5
1N1877A
CR7
1N1680A

R6
39K
CR4
1N1877A
CR6
1N1877A

R7
1.1K
1W
-12
R8
1.1K
1W
-12
R9
8.5K

R10
11K

CR8
1N540
6
7
C3
15 MF
150 VDC
CR14
1N1680A
BIAS
27
R11
11K

CR9
1N540
8

CR10
1N540
9
10
R12
96 Ω
14.8
C4
10 MF
150 VDC
CR15
1N1767
FILAMENT

CR11
1N540
11

CR12
1N1564
12
13
R38
2.6 3W
-25
C5
150 MF
150 VDC
SOURCE

CR13
1N1564
14

CALIBRATE
R31
10K
C33
40 MF
C16
.25 MF
CALIBRATE
S2
COARSE ZERO
R32
50K

ZERO
R33
5K
C15
40 MF

FIGURE 12
SCHEMATIC